Year 12 Exam May 2013 Mark scheme

Section A

1. (a) *Ionic:*
(electrostatic) attraction between oppositely charged ions/cations and anions/positive and negative ions;
Do not accept answers such as compounds containing metal and non-metal are ionic.

Metallic:
(electrostatic attraction between lattice of) positive ions/cations/nuclei and delocalized electrons / (bed of) positive ions/cations/nuclei in sea of electrons / *OWTTE*; *[2]*

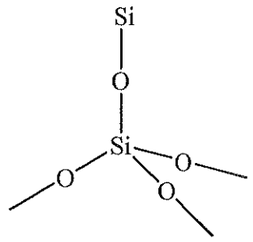
(b) (i) T: 4 **and** m: 3 **and** p: 3; *[1]*

(ii) $n = (65.0 / 65.02) = 1.00\ (\text{mol})$; *[1]*
No penalty for using whole number atomic masses.

(iii) $n(N_2) = \left(\frac{3}{2} \times 1.00 = \right) 1.50\ (\text{mol})$;
$T = \left((25.00 + 273.15) =\right) 298.15\ \text{K} / \ (25.00 + 273) = 298\ \text{K}$;
$p = 1.08 \times 1.01 \times 10^5\ \text{Pa} / 1.08 \times 1.01 \times 10^2\ \text{kPa} / 1.09 \times 10^5\ \text{Pa} / 1.09 \times 10^2\ \text{kPa}$;
$V = \frac{nRT}{p} = \frac{(10^3)(1.50)(8.31)(298.15 / 298)}{(1.08 \times 1.01 \times 10^5)} = 34.1\ (\text{dm}^3)$; *[4]*
*Award **[4]** for correct final answer.*
*Award **[3 max]** for 0.0341 (dm^3) or 22.7 (dm^3).*
*Award **[3 max]** for 34.4 (dm^3).*
*Award **[2 max]** for 22.9 (dm^3).*
*Award **[2 max]** for 0.0227 (dm^3).*
*Award **[2 max]** for 0.034 (dm^3).*

(c) (i) sodium could react violently with any moisture present / sodium is (potentially) explosive / sodium (is dangerous since it is flammable when it) forms hydrogen on contact with water / *OWTTE*; *[1]*
Do not accept answers such as sodium is dangerous or sodium is too reactive.

(ii) *Structure:*
drawing of giant structure showing tetrahedrally arranged silicon;
Minimum information required for mark is Si and 4 O atoms, in a tetrahedral arrangement (not 90° bond angles) but with each of the 4 O atoms showing an extension bond.



Bonding:
(giant/network/3D) covalent; *[2]*

(d) (i) $\left(\frac{34.1}{0.0400}\right) = 853 \text{ dm}^3 \text{ s}^{-1} / \left(\frac{1.50}{0.0400}\right) = 37.5 \text{ mol s}^{-1}$; *[1]*
Accept 851 dm^3 s^{-1}.
Units required for mark.

(ii) more energetic collisions / more species have energy $\geq E_a$; *[1]*
Allow more frequent collisions / species collide more often.

2. (a)

Symbol	$^{59}Co^{3}$	^{60}Co	^{125}I
Number of protons	27	27	53
Number of neutrons	32	33	72
Number of electrons	24	27	53

[2]

*Award **[2]** for all four correct.*
*Award **[1]** for two or three correct.*

(b) Co-60 emits (penetrating) gamma radiation/rays / *OWTTE*; *[1]*
Allow because Co-60 emits radiation which kills/treats cancer cells.
Do not allow answers such as Co-60 is radioactive or Co-60 treats cancer as single statements.

(c) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^6$; *[1]*
Do not award mark for $[Ar]3d^6$.
Do not allow $1s^2\,2s^2\,2p^6\,3s^2\,3p^6\,4s^1\,3d^5$.

3.

(a) all heat is transferred to water/copper sulfate solution / no heat loss;
specific heat capacity of zinc is zero/negligible / no heat is absorbed by the zinc;
density of water/solution = 1.0 / density of solution = density of water;
heat capacity of cup is zero / no heat is absorbed by the cup;
specific heat capacity of solution = specific heat capacity of water;
temperature uniform throughout solution; *[2 max]*
*Award **[1]** each for any two.*
Accept energy instead of heat.

(b) (i) $T_{final} = 73.0\,(^{\circ}C)$;
Allow in the range 72 to 74 (°C).

$\Delta T = 48.2\,(^{\circ}C)$; *[2]*
Allow in the range 47 to 49 (°C).
*Award **[2]** for correct final answer*
Allow ECF if T_{final} or $T_{initial}$ correct.

(ii) 10.1 (kJ); *[1]*
Allow in the range 9.9 to 10.2 (kJ).

(c) $\left(n_{Zn} = n_{CuSO_4} = \frac{1.00 \times 50.0}{1000}\right) = 0.0500\,(\text{mol})$; *[1]*

(d) $-201\,(\text{kJ mol}^{-1})$; *[1]*
Allow in the range −197 to −206 ($kJ\,mol^{-1}$).
Value must be negative to award mark.

4.

(a) (i) $n(\text{Pb}): \left(\frac{64.052}{207.19}\right) = 0.30915\ (\text{mol})$

$n(\text{C}): \left(\frac{29.703}{12.01}\right) = 2.473\ (\text{mol})$

$n(\text{H}): \left(\frac{6.245}{1.01}\right) = 6.18\ (\text{mol})$

Do not penalize if integer values of atomic masses used.
Accept alternative calculation method.
Award [2] for three correct.
Award [1] for any two correct.

PbC_8H_{20}; *[3]*

(ii) PbC_8H_{20}; *[1]*

(iii) $PbC_8H_{20} + 14O_2 \rightarrow PbO_2 + 8CO_2 + 10H_2O$

correct reactants and products;
correct coefficients; *[2]*
M2 can only be scored if M1 correct.

5. (a) negative;
liquid more ordered than gaseous phase or *vice-versa* / *OWTTE*; *[2]*

(b) (i) $\Delta H_f^{\ominus}$ of an element (in its most stable state) is zero (since formation of an element from itself is not a reaction) / *OWTTE*; *[1]*
Do not allow an answer such as because they are elements.

(ii) $\Delta H^{\ominus} (= (1)(-20.6) - (1)(-53.1)) = 32.5\ (\text{kJ mol}^{-1}) / 32500\ (\text{J mol}^{-1})$; *[1]*
Allow 32.5 (kJ) or 3.25×10^4 (J).

(iii) $\Delta G^{\ominus} (= (1)(-33.6) - (1)(-53.6)) = 20.0\ (\text{kJ mol}^{-1}) / 20000\ (\text{J mol}^{-1})$;
Allow 20.0 (kJ) or 2.00×10^4 (J).
non-spontaneous; *[2]*

(iv) $\Delta S^{\ominus} (= (\Delta H^{\ominus} - \Delta G^{\ominus}) / T = (32.5 - 20.0)(1000) / 298) = 41.9\ (\text{J K}^{-1}\ \text{mol}^{-1}) /$
$4.19 \times 10^{-2}\ (\text{kJ K}^{-1}\ \text{mol}^{-1})$; *[1]*
Allow 41.9 ($J K^{-1}$) or 4.19×10^{-2} ($kJ K^{-1}$).

(v) $T (= \Delta H / \Delta S = (32.5 \times 1000) / (41.9)) = 776\ (\text{K})$; *[1]*

$0 = 32.5 - K \times 0.041$

$K = \frac{32.5}{0.0419}$

$= 776\ K$ (3sf)

(iv) $20 = 32.5 - 298x$

$20 - 32.5 = -298x$

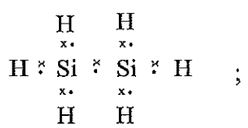
$-12.5 = -298x$

$x = \frac{12.5}{298} = 0.0419\ kJ\ mol$

Section B

6.

(a) (i)



;

[1]

Accept any combination of lines, dots or crosses to represent electron pairs.

(ii) 109 / 109.5 / 109 28';
four/tetrahedrally arranged negative charge centres/electron domains/electron pairs (around central/silicon atom) / equal repulsion between bonding pairs (around central/silicon atom) / *OWTTE*; *[2]*
M2 is an independent marking point.
Reference must be made to negative or electron.
Do not accept tetrahedral molecule.

(iii) sp^3; *[1]*

(iv) C–H;
larger difference in electronegativity (for C–H bond) / smaller difference in electronegativity (for Si–H bond) / ΔEN (CH) = 0.4 and ΔEN (SiH) = 0.3; *[2]*

(v) both (molecules) non-polar;
both (molecules) symmetrical / polar bond effects cancel out / *OWTTE*; *[2]*

(vi) stronger/larger/greater van der Waals'/London/dispersion forces;
Do not accept stronger/larger/greater intermolecular forces.

more electrons / stronger instantaneous dipole; *[2]*
Do not accept larger mass.

(b) (i) ($\sum \ddot{e} H_f^\circ$ (products) =) –5360 (kJ);
($\sum \ddot{e} H_f^\circ$ (reactants) =) +160 (kJ);
= –5520 (kJ); *[3]*

(ii) (–1560 × 2 =) –3120 (kJ); *[1]*

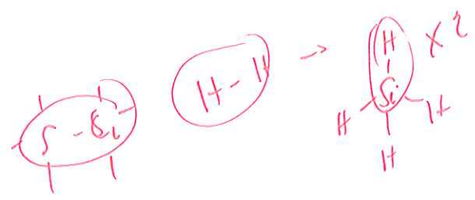
(iii) *Structure:*
CO_2 molecular and SiO_2 three-dimensional/network/giant lattice/giant covalent/macromolecular/repeating tetrahedral units;
CO_2 linear and SiO_2 tetrahedral;

Intramolecular Bonding:
covalent bonds in CO_2 and SiO_2;
double bonds in CO_2 and single bonds in SiO_2; *[3 max]*
Accept diagrams showing bonding types (double and single) within the structures.

(c) *Bonds broken:*
6Si–H, Si–Si, H–H / (+)2570 (kJ);
Bonds formed:
8Si–H / (–)2544 (kJ);
+26 (kJ);

OR

Bonds broken:
Si–Si, H–H / (+)662 (kJ);
Bonds formed:
2Si–H / (–)636 (kJ);
+26 (kJ); *[3]*



(d) (i) 1 to 3;
Accept any answer in this range: pH ≤ 3.

HCl/strong acid formed;
$SiCl_4(l) + 4H_2O(l) \rightarrow Si(OH)_4(s) + 4HCl(aq)$; *[3]*

(ii) *Aqueous solution:*
mobile ions/charged particles present;

Liquid:
molecular covalent / no (mobile) charged particles/ions; *[2]*

7.

(a) (i) ionization, acceleration, deflection/separation
Award [1] for all three names and [1] for correct order.
Award [1] for two names in correct order.

Ionization:
sample bombarded with (high-energy/high-speed) electrons / *OWTTE*;
Acceleration:
electric field/oppositely charged plates;
Deflection:
(electro)magnet/magnetic field; *[5]*

(ii) ratio of average/mean mass of an atom to the mass of C-12 isotope / average/mean mass of an atom on a scale where one atom of C-12 has a mass of 12 / sum of the weighted average/mean mass of isotopes of an element compared to C-12 / *OWTTE*; *[1]*
Award no mark if "element" is used instead of "atom".

(iii) $A_r = \frac{(46\times13.5)+(47\times7.4)+(48\times73.7)+(49\times5.4)}{100}$;
47.7; *[2]*
Accept atomic mass units but award [1 max] if other units given.
Answer must be given to one decimal place.

(iv) prevents collisions/unintentional deflections / *OWTTE*; *[1]*

(b) (i) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^2$;
4s; *[2]*

(ii) 4^{th} electron removed from 3d and 5^{th} electron removed from 3p;
10^{th} electron removed from 3p and 11^{th} electron removed from 3s;

Accept either of the following answers for the third mark:
electrons removed from lower energy level / energy level closer to nucleus are attracted more strongly;
greater effective nuclear charge / s electrons more penetrating; *[3 max]*

(iii) +2, +3, +4; *[1]*

(iv) (colour) due to partially filled/incomplete d sub-level/orbital;
d sub-level is split / d orbitals are split;
$Ni^{2+}(aq)$ has incomplete 3d sub-level/orbital but $Sc^{3+}(aq)$ has no 3d electron/empty/d sub-level;
electrons move from lower to higher (sub)levels when they absorb energy/light;
$Ni^{2+}(aq)$ (appears green because it) absorbs red; *[5]*

(c) (i) line spectrum;
(lines) converge at high energy/frequency/shorter wave length/blue end of spectrum; *[2]*
Both marks can be awarded if suitable diagram is given.

(ii) electron transition from higher to lower/second energy levels;
each transition causes emission of light of specific frequency/wavelength/ energy;

each transition/line is related to energy difference / $\Delta E = \frac{hf \,/\, hv \,/\, hc}{\lambda}$;

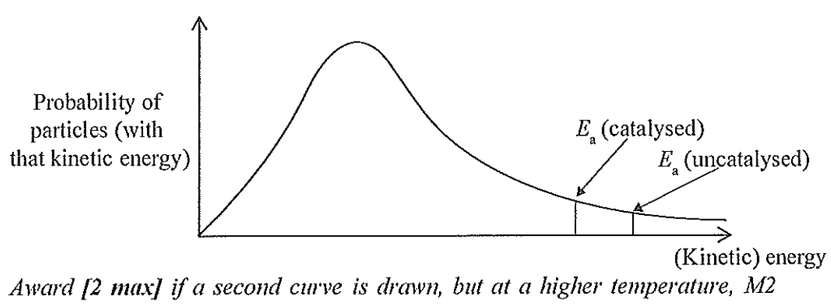
energy levels in hydrogen atom are closer/converge at higher energy; *[3 max]*

8. (a) minimum energy needed (by reactants/colliding particles) to react/start/initiate a reaction; *[1]*
Allow energy difference between reactants and transition state.

(b) catalyst;
regenerated at end of reaction / *OWTTE*; *[2]*

(c) (i) (system) absorbs/takes in heat from surroundings / *OWTTE*; *[1]*
Allow standard enthalpy change/ $\Delta H^{\ominus}$ positive.
Allow bond breaking more energetic then bond formation / OWTTE.
Absorbs/takes in heat alone not sufficient for mark.

(ii) *Curve showing:*
general shape of Maxwell-Boltzmann energy distribution curve;
correct position of E_a (catalysed) **and** E_a (uncatalysed);
labelled y-axis: probability of particles (with that kinetic energy) **and** *labelled x-axis:* (kinetic) energy; *[3]*
Allow number/fraction/proportion of particles (with kinetic energy) for y-axis label, but do not allow amount or particles.



*Award **[2 max]** if a second curve is drawn, but at a higher temperature, M2 will not be scored here.*

(d) (i) change in concentration of reactant/product with time / rate of change of concentration; *[1]*
Increase can be used instead of change for product or decrease can be used instead of change for reactant.
Allow mass/amount/volume instead of concentration.
Do not accept substance.

(ii) pressure is lower/moderate **and** temperature is higher in Haber process / ~ 200 atm (pressure) **and** ~ 700 K (temperature) used in Haber process;

Pressure:
high pressure shifts equilibrium to right;
high pressure (faster rate but) expensive/dangerous / greater capital and running costs;

Temperature:
low temperature shifts equilibrium (even further) to right;
low temperature gives slower rate (but high yield);

high pressure increases yield **and** lower temperature decreases rate;
Accept converse argument.

(not possible to have high yield and fast rate simultaneously therefore) compromise needed / *OWTTE*; *[4 max]*

(e) (i) dative (covalent)/coordinate;
carbon monoxide/CO / hydronium (ion)/H_3O^+ / ammonium (ion)/NH_4^+ / aluminium chloride/Al_2Cl_6 / any relevant transition metal complex (*e.g.* $[Ni(NH_3)_6]^{2+}$); *[2]*
Accept $AlCl_3$.

(ii) rate = $k[BF_3][NH_3]$;
second (order)/2°;
$k = 3.40\ dm^3\ mol^{-1}\ s^{-1}$; *[3]*
Allow units of L mol^{-1} s^{-1} or M^{-1} s^{-1}.
Units required for mark.

(f) (i) N_2O_2; *[1]*

(ii) ($[H_2]$ appears in rate expression so) step 2 rate-determining/rds/slow step; *[1]*
Allow "since step 1 involves 2NO and step 2 involves H_2 and as all 3 molecules are involved in rate expression, then two steps must have approximately same rate" / OWTTE.

(g) ($k_2 >> k_1$ so) step 1 rate-determining/rds/slow step;
two molecules of NO_2 involved in step 1 consistent with rate expression / rate of overall reaction must equal rate of step 1 which is rate = $k_1\ [NO_2]^2$ / *OWTTE;* *[2]*

2.67

(h) $E_a = -R \times m$;

measurement of gradient from **two** points on line;

Accept a gradient in range -2.14×10^4 *K to* -2.27×10^4 (K).

correct answer for E_a ;

correct units kJ mol^{-1}/J mol^{-1} corresponding to answer; ***[4]***

Allow kJ or J.

A typical answer for $E_a = 1.85 \times 10^2$ *kJ* mol^{-1}.

Allow answers for E_a *in range* 1.75×10^2 *kJ* mol^{-1} *to* 1.91×10^2 *kJ* mol^{-1}.

*Award **[4]** for correct final answer with some working shown.*

*Award **[2 max]** for correct final answer without any working shown.*

check eq
units kJ/mol (cells)

9. (a) (i) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^6 4s^2$ / $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^6$; *[1]*

(ii) $[Ar]\,3d^5$; *[1]*

(iii) lone pair of electrons (on C);
CN^- acts as a Lewis base / Fe^{3+} acts as a Lewis acid;
dative covalent/coordinate bond formed (between CN^- and Fe^{3+});
ligands occupy an octahedral shape around central metal ion / coordination number of Fe^{3+} is 6; *[4]*

(iv) d sub-level splits (into two sets of orbitals of different energy) /_ _ _ ↕ ΔE;
colour due to electron transitions between (split) d orbitals; *[2]*

(b) (i) $2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$; *[1]*

(ii) Pt/platinum / V_2O_5/vanadium(V) oxide/vanadium pentoxide; *[1]*

(iii) provides a reaction pathway with lower activation energy;
more molecules/particles have sufficient energy to react; *[2]*

(iv) reduces energy costs (as reaction occurs at lower temperatures) / *OWTTE*;
catalyst can be reused;
increases reaction rate so more product produced in a given time / *OWTTE*; *[2 max]*

(v) entropy decreases;
products have fewer moles of gas than reactants; *[2]*

(vi) less spontaneous at higher temperatures;
spontaneous when $\Delta G < 0 / \Delta G = \Delta H - T\Delta S$;
$-T\Delta S$ always positive so spontaneous when $T\Delta S < \Delta H$ / *OWTTE*; *[3]*

(c) (i) *k*:
rate constant;

A:
Arrhenius constant / frequency/pre-exponential factor; *[2]*

(ii) gradient $= \frac{-E_a}{R}$ / E_a = –gradient × *R*;
$\left(= -(-16) \times 8.31\right) = +133\ (kJ\ mol^{-1}) / 1.33 \times 10^5\ (J\ mol^{-1})$; *[2]*

(iii) ln A = (intercept on *y*-axis =)23.2 ;
$A = 1.190 \times 10^{10}$; *[2]*